

FACULTY COLUMN:

Systems Biology—What's All the Buzz About?

The term “systems biology” entered the vocabulary of the scientific community only a few years ago, but what does it really mean?

Front and center is a clear focus on systems, which are collections of components that interact with each other and in the process make something happen. Typical components in the engineering world – screws, wires, wheels and transistors – don't do much when left to their own devices. However, let clever engineers put them together and the parts seemingly come to life, with the creation of a television set or a car. Something dynamic emerges out of a collection of objects.

On a coarse level, biological systems have quite a few similarities with engineered systems, but they are incomparably more complicated and intriguing. Not only do they move, but they also reproduce and develop on their own out of a single cell.

In contrast to cars, they search for their own food and adapt to new situations and even to entirely novel environments. They respond to challenges appropriately and intelligently, although the latter is sometimes disputed.

The grand challenge of systems biologists is to understand how biological systems function. This is an important goal, not just from an academic perspective, but also for very practical reasons.

Understanding how cellular control works—or fails—will suggest new options for cancer treatment. Insights into the organization of bacterial pathways will help harness the power of microorganisms for the biotechnological production of valuable organics or bulk products like ethanol and for novel, yet natural, means of cleaning up the environment.

Integrative systems biology adds a new and exciting set of tools to the repertoire of biological research techniques. It uniquely complements the more traditional paradigm of “reductionist” experimentation in which well-controlled experiments crisply focus on the characterization of select components or processes.

Reductionist biology has provided researchers with a rapidly growing list of molecular building blocks, along with details on their features and functions. The results of this reductionist paradigm have been truly amazing and have affected every aspect of life. Just look at the advances in medicine over the past decades!

Systems biology complements the reductionist paradigm by revealing how higher-level functionality emerges from interactions among the building blocks. They are intimately interwoven – after all, how could systems biology succeed without detailed knowledge of the players in a system? And why would anyone be interested in one particular gene or signaling process if it did not contribute to

some higher-level function that is important in a cell, organism or ecological system?

Biological systems are complex and modeling them requires researchers in many areas of expertise to unite. The three main areas of expertise are described here. The first typically uses high-throughput experiments that, for instance, simultaneously measure the expression of thousands of genes in an organism. The ultimate goal of these investigations is to establish complete molecular inventories and characterize the function of each biological component.

The second area of expertise falls into the realm of engineering. Without innovative machinery, none of the high-throughput biology would be possible. Brilliant engineering advances in sensing, probing, miniaturization, robotics and many other areas allow biological building blocks to be investigated rapidly and with a clarity and resolution never seen before.

The third area of expertise is computational. Here the goal is the construction of numerical models that reliably quantify the interactions among the many components and processes within a biological system. Following Richard Feynman's observation, “What I cannot create, I do not understand,” and glancing at the enormous successes in engineering, the “creating” is accomplished first with computer models, whose results later guide the creation of actual, yet synthetic, biological systems.

The technical aspects of experimentation, device creation and computation will certainly be the crucial drivers of the success of systems biology. Motivating these drivers is a systems-oriented mindset.

Systems biology encourages us to look at the living world with different eyes. Systems biologists appreciate the role and function of each biological building block – not in isolation, but as a vital part in the larger context of intricately fine-tuned machines that hierarchically form larger ensembles and, in concert with all parts, bring innate molecules to life.

Systems biology is a fascinating, mind-altering endeavor. So beware – engaging in systems biology may irreversibly change your views of the living world!

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